Previous Section

Chapter 4 -- Test

A. -- Introduction for Test Critical Path Templates

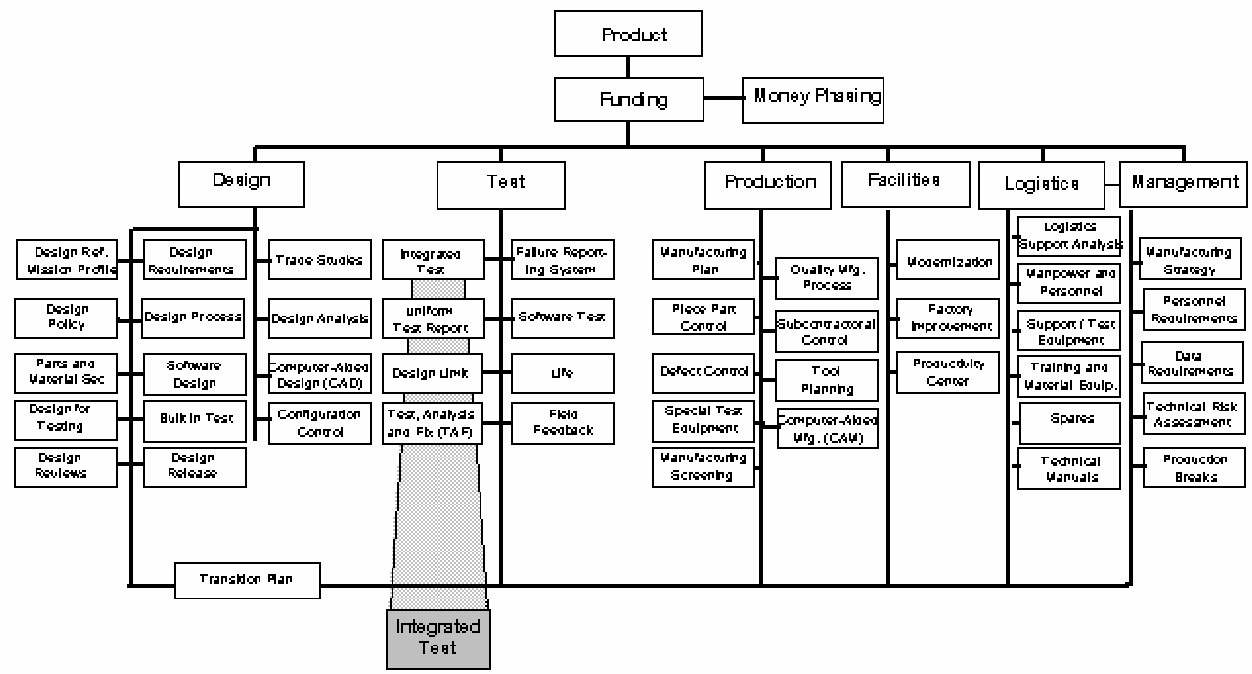
During the development cycle of a weapon system various tests are performed by subcontractors, prime contractors, and the Government. In the early stages of development, these tests are used in evaluating design approaches and selecting design solutions for further development. As the design matures, the tests become more complex in attempting to provide confidence that the weapon system will perform satisfactorily in the actual operational environment.

As weapon systems have become more sophisticated, test requirements have been added with little consideration being given to possible duplication of effort or the elimination nation of older tests that no longer are needed. Attempts also have been made to "standardize" test environments. In many instances, these "standard" environments have shown little relation to the actual operational environment, resulting in costly engineering changes to weapon systems, after initiation of production and deployment, in order to correct basic design deficiencies that would have been detected" before production had a proper environment been used.

The DSB task force reviewed the test and "evaluation experience of several major DoD programs and the contributions of the test programs towards reducing the risk of transition from development to production" on. Areas investigated included topics such as integrated test plans; operational test environments; reliability development tests; reliability demonstration tests; software tests; Government participation in full-scale engineering development tests; initial operational test and evacuation; application of the test, analyze, and fix (TAAF) philosophy during transition; and the feedback of information from initial field use of production weapon systems.

The issues and guidelines provided in this section represent the most significant areas requiring special management attention in order to reduce the risk of transition from development to production. The process to integrate and document test requirements for the end item begins with the preparation and generation of the test and evacuation master plan (TEMP).

B. -- Integrated Test



Area of Risk

Although every development program has a defined test plan, this plan usually specifies a series of standard tests that have not been integrated properly. Integration includes the careful accounting of objectives, environments, test article configurations, data requirements, and schedules. Recognizing that T& E is a major cost driver, the objectives of test integration are to minimize overlaps and gaps, to collect maximum intelligence from every test, and to ensure a smooth and effective test program at minimum cost. The absence of a carefully integrated test plan is a certain indicator of a high risk program.

Critical parameters and characteristics measured in production acceptance tests (PATs) do not give a sufficiently high level of confidence that the product meets its specification. Production configuration changes introduced without recertifying the validity of the PAT further increase product risk.

Outline for Reducing Risk

- Early in the program initiation phase an integrated test plan (ITP) is prepared by the prime contractor for Government approval that maximizes efficiency in testing, as follows:
  - Includes all development and qualification tests (prime contractor, subcontractors, and Government) at the system and subsystem levels.
  - Identifies duplicate test activities and missing test activities.
  - Provides for the most efficient use of test facilities and test resources.
- This ITP is updated periodically.

• Government participation in contractor testing of weapon systems includes operating the system a portion of the time during FSD.

• Initial operational test and evaluation (lOT& E) is conducted during the transition from development to production, using the latest available configuration, when possible.

• Qualification test articles are representative of production units.

• Production acceptance testing is conducted on all production items, to ensure the continuing effectiveness of the manufacturing processes, equipment, and procedures. This includes revalidation of acceptance test procedures. when significant changes occur in the configuration or the production processes.

• Ensure that test tolerances are funneled from component (most restrictive) to system (least restrictive) within system specification performance parameters.

• Reasonable probability that the product meets previously qualified performance requirements is demonstrated by the production acceptance test, in terms of both thoroughness and severity, as a prerequisite to product acceptance by the Government.

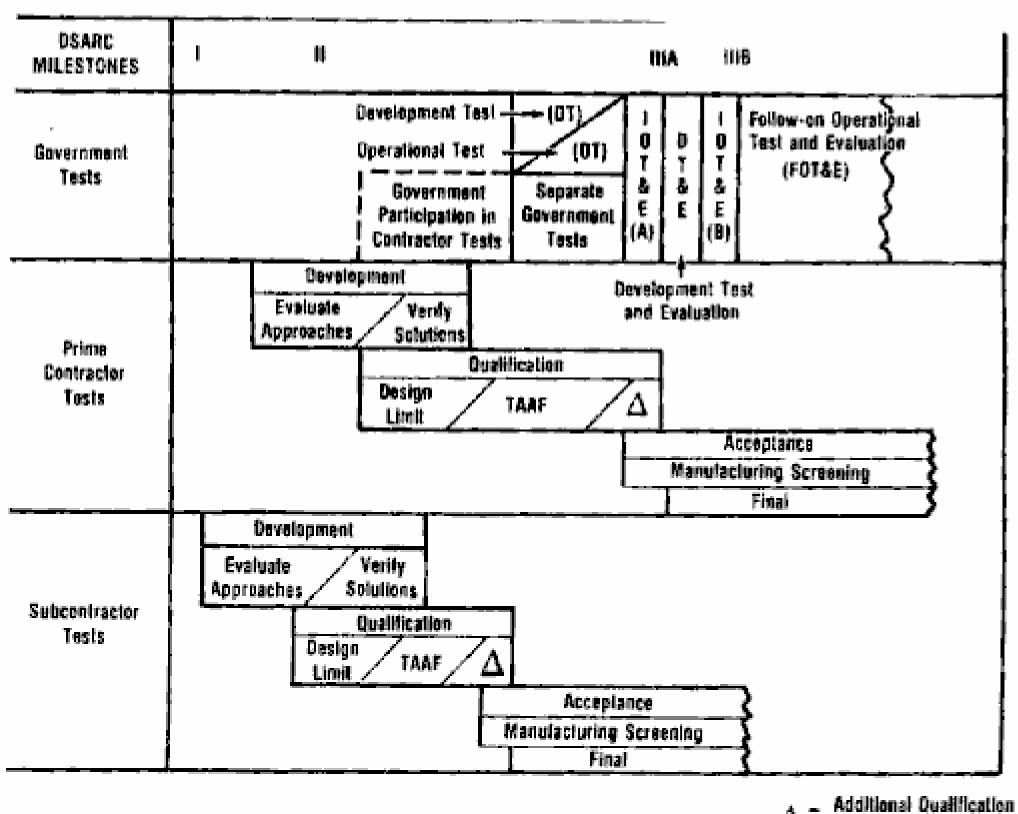
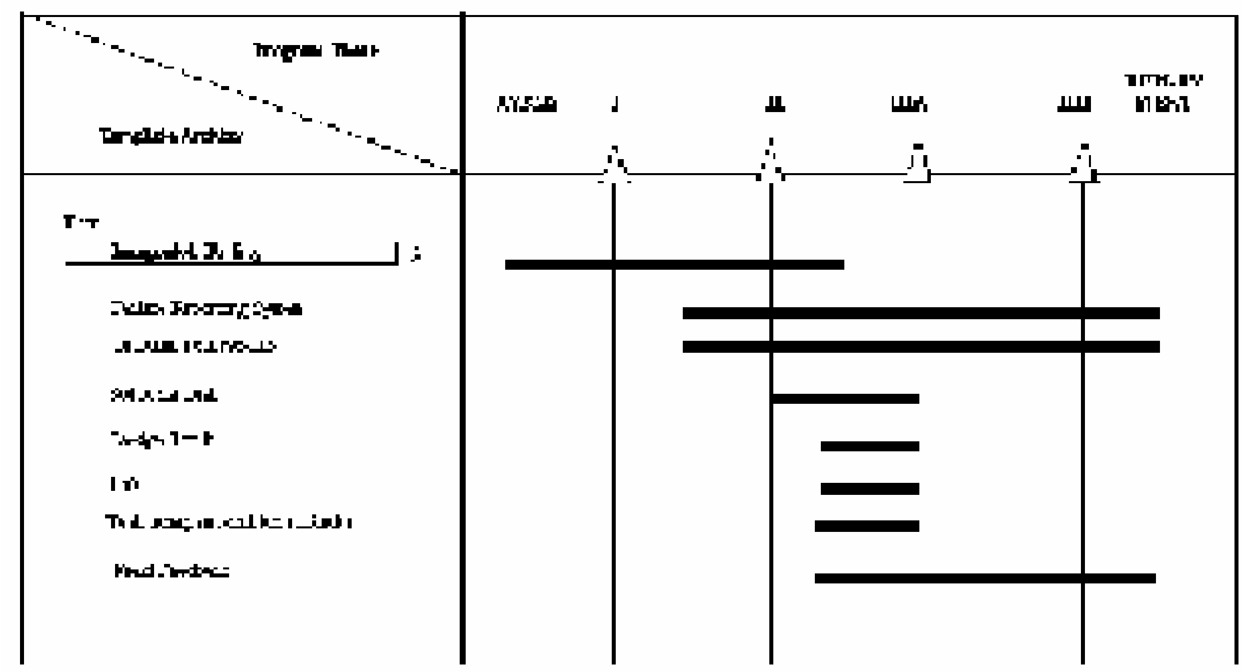


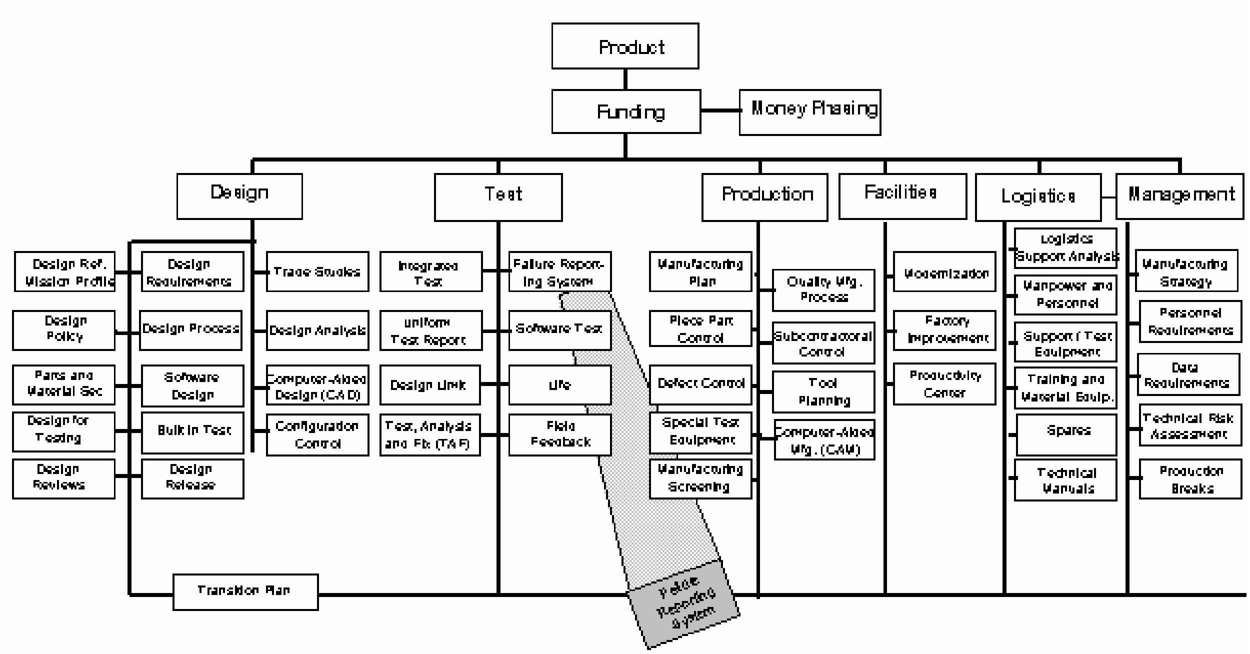
Figure 4-1. Integrated Test Plan

• Figure 4-1. shows the essential elements of an ITP.

To ensure that all development tests are properly time phased, that adequate resources (for example, test articles, test facilities, funding, and manpower) are available, and that duplicative or redundant testing is eliminated, a properly integrated test program is required. This activity must start early in concept development to continue into FSD.

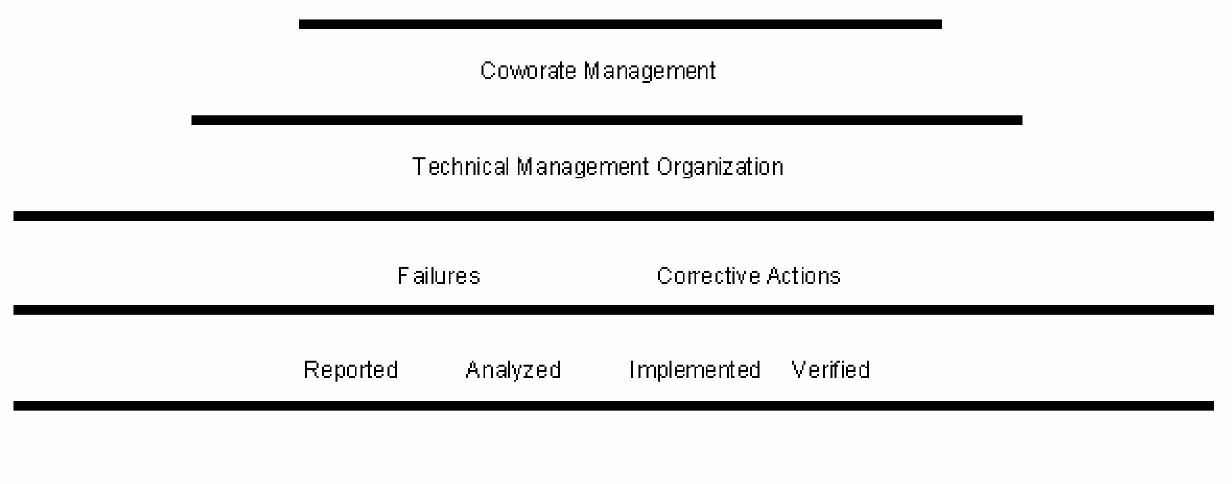


C. -- Failure Reporting System



Area of Risk

The ultimate objective of a failure “reporting, analysis, and corrective action system (FRACAS) is to devise corrective actions, which prevent failure recurrence, for incorporation into the system or equipment. Although there are several military standards, such as Military Standard (MIL-STD) 785B (reference (e)) and MIL-STD 781 C (reference (f)), that require FRACASS, the implementation of these requirements has been managed poorly, defined improperly, and undisciplined. The flow down of requirements from prime contractor to subcontractors has not been uniform, analysis of all failures has not been required, the timely close-out of failure reports has been overlooked, and systems for alerting higher management to problem areas have been missing.

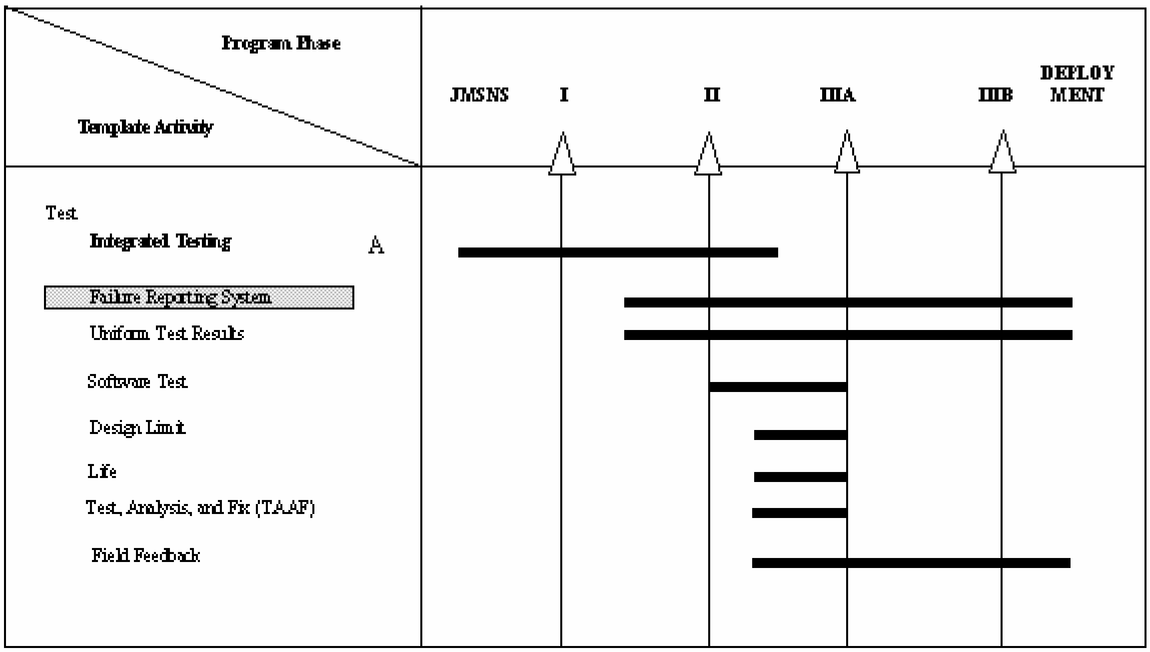


Outline for Reducing Risk

- A central technical organization is responsible for implementation and monitoring.
- A FRACAS is initiated at the piece pat level.
- Uniform requirements are imposed on subcontractors, prime contractors, and Government activities.
- All failures are reported.
- All failures are analyzed to sufficient depth to identify failure cause and necessary’ corrective actions.
- All failure analysis reports are closed out within 30 days of failure occurrence, or rationale is provided for any extensions.
- Corporate management automatically is alerted to failures exceeding close-out criteria.
- Corporate management automatically is alerted to ineffective corrective actions.
- Small subcontractors lacking facilities for in-depth failure analysis arrange for the use of prime contractor, Government, or independent laboratory facilities to conduct such analyses.

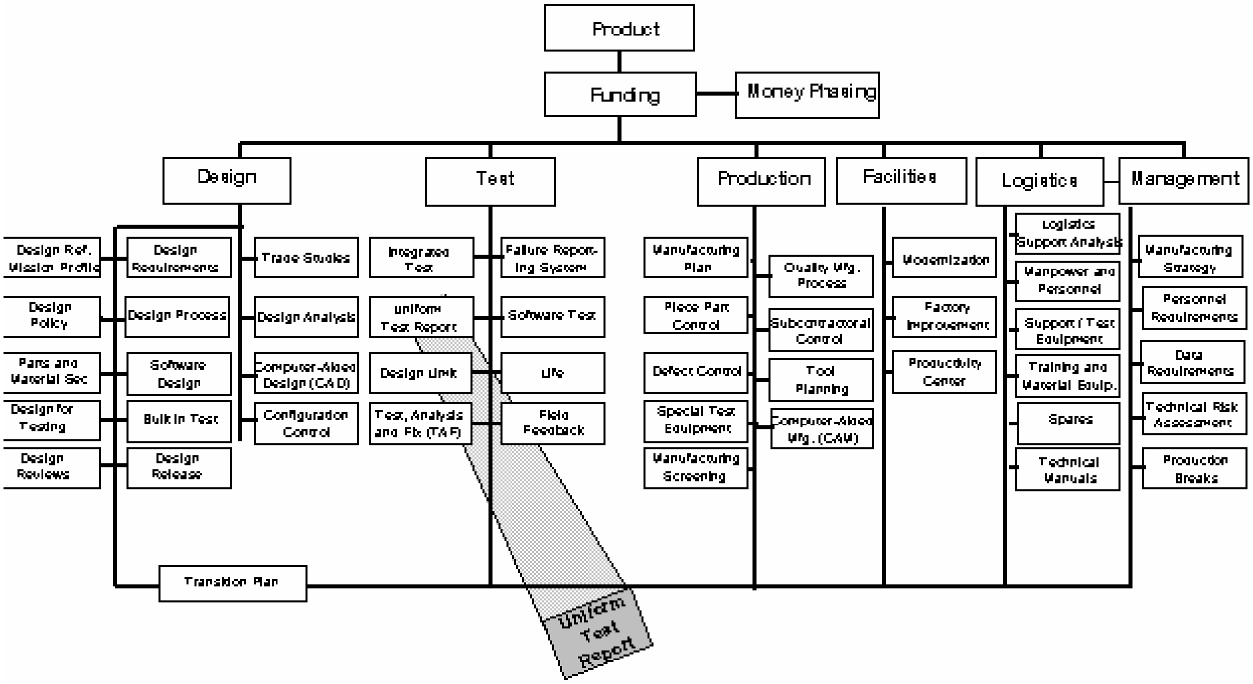
• Criticality of failures is prioritized in accordance with their individual impact on operational performance.

Timeline



A FRACAS will be effective only if the reported failure data is accurate. The failure reporting system is initiated with the start of the test program and continues through the early stages of development.

D. -- Uniform Test Report



Area of Risk

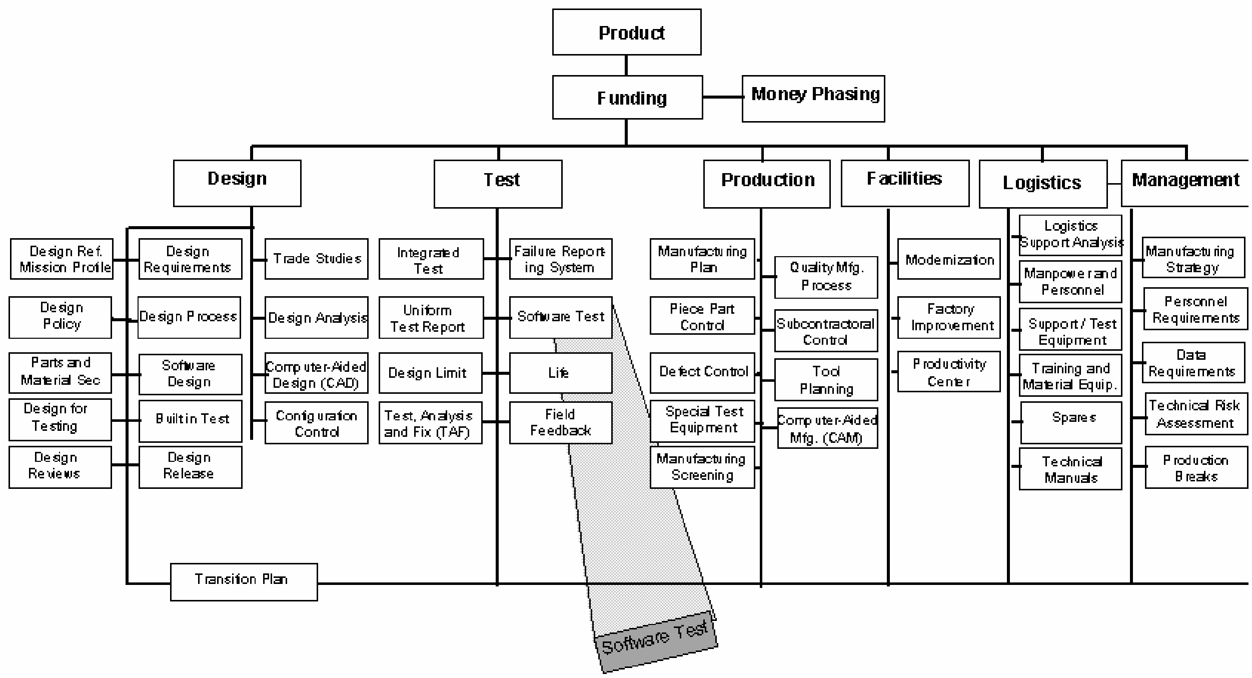
Formal reliability development tests using the TAAF methodology normally are performed for failure mode identification and elimination. During these tests, all results are reported in a format that provides acquisition managers with visibility of actual versus predicted reliability growth. Results from other tests being performed during the development and transition phases usually are reported in different formats. This change in format precludes merger of test results and prevents an overall assessment of design maturity by acquisition managers.

Outline for Reducing Risk

- All test results, including initial field operations, are reported using the TAAF format, an example of which is shown in figure 4-2.
- Plotted results are used to assess design maturity and readiness for transition from development to production.

All test data must be collected in the special TAAF format and analyzed to determine reliability growth. Reporting test results in the TAAF format begins with the earliest program testing and continues into service *use* to allow a uniform baseline to evaluate failures and corrective actions.

<u>E. -- Software Test</u>



Area of Risk

There is no way to test all possible paths during a development and acceptance test for a complex system involving immense logic complexity. Some of these paths eventually will be exercised after the system is deployed and some legitimate user interfaces will occur that were not tested specifically. These will result in software errors.

Many past studies on hardware illustrate how the cost of correcting a design error multiplies if the problem is not found until acceptance testing, production, or deployment. The same applies to software, but the cost for correcting software design errors after the design phase multiplies at a much greater rate.

Figure 4-3. is based on combined data from four major contractors and shows a multiple of 100:1 for cost to correct a design error after the system is operational.

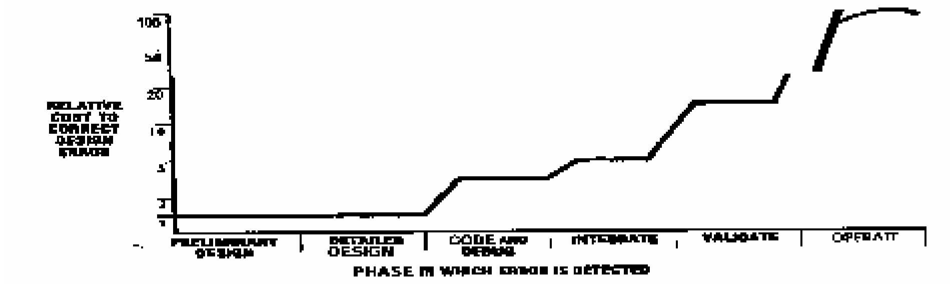


Figure 4-3. Relative Cost to Correct Design Error

Outline for Reducing Risk

- Up front money is available for testing software early in the design phase to prevent design and coding errors from being discovered after deployment.

- The software design allows the product to be testable. The test group is an active participant in software design reviews to ensure that the design is testable to the greatest degree.

- An independent test group is used to initiate the software test plan and to initiate testing at the functional module level early in the program.

- Test readiness reviews are used to ensure good software test planning.

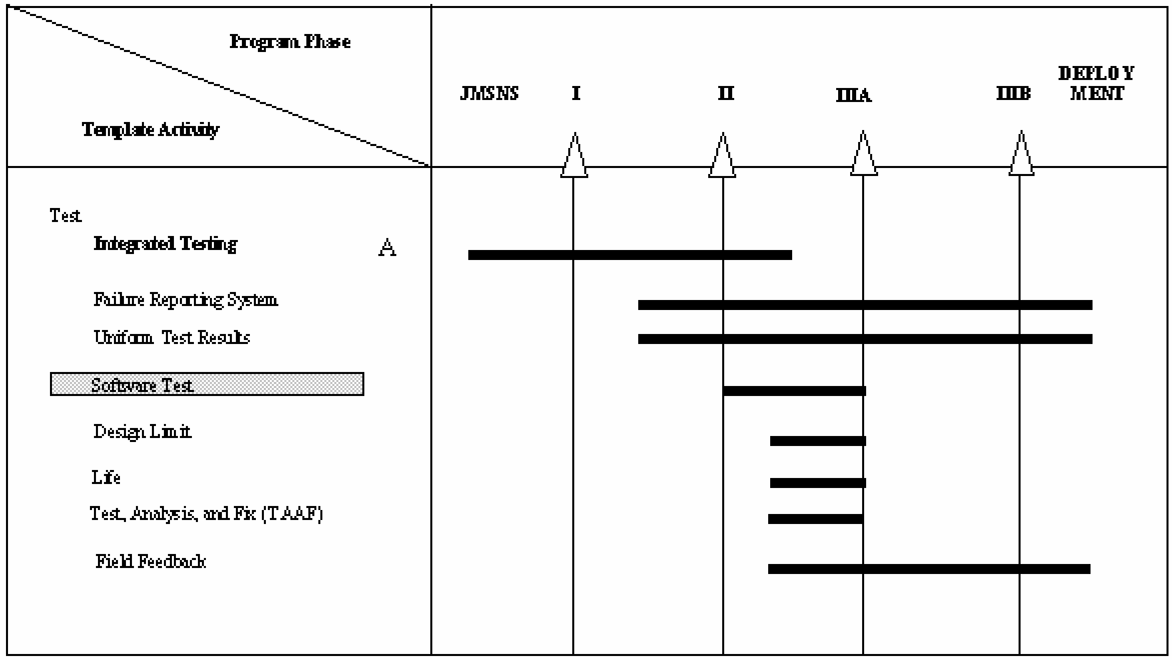
- For extremely high reliability requirements, the verification and validation approach is used. An independent test group is used to verify by analysis or test every important test action.

- Useful definitions of error and failure are developed and software reliability growth is tracked during all test phases using a closed loop failure reporting system. Every failure is analyzed placing special emphasis on resolving anomalies.

- Stress testing and “worst case” testing are utilized to ensure that adequate design margins exist in memory loading, data rates, port timing, and other critical parameters.

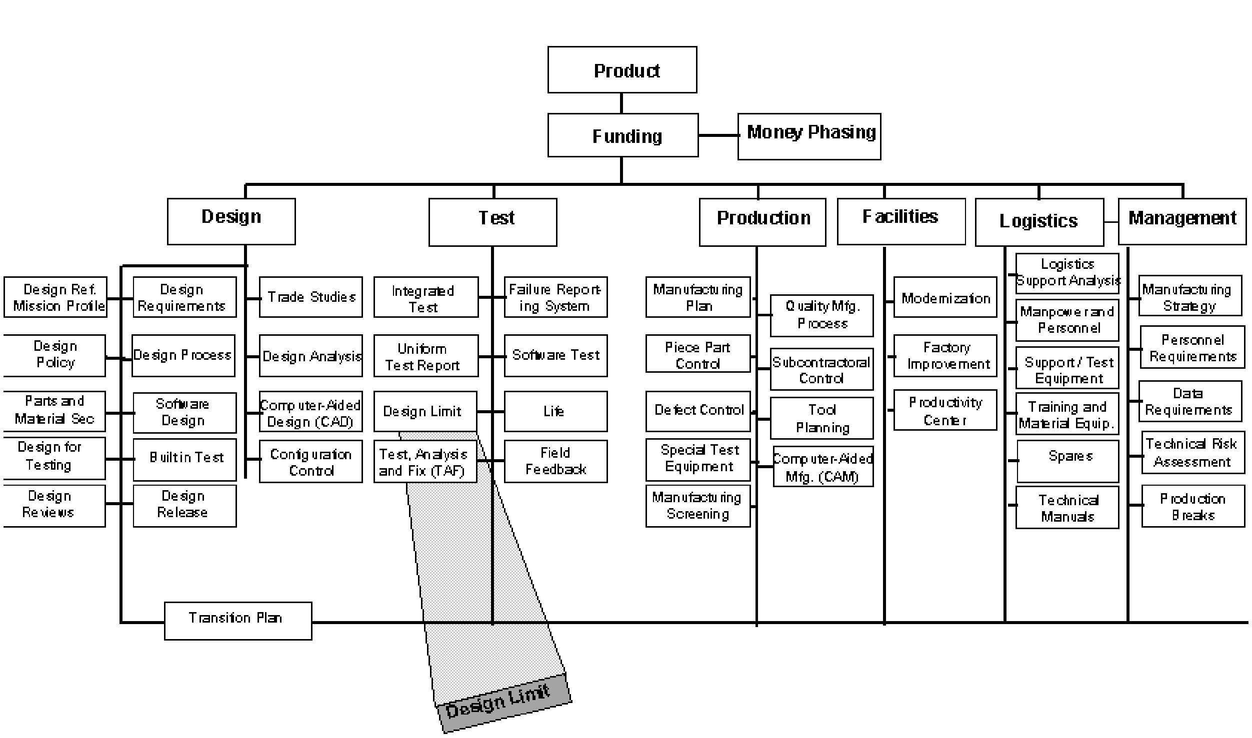
- Security requirements are considered during software testing.

Timeline



The best approach in testing software is through testing at each of the early stages of design and coding to reduce the probability of error escaping and surfacing during system integration tests and field use. Assurance of software/hardware interface compatibility is obtained by exhaustively testing the software in a total system, test bed.

<u>F. -- Design Limit</u>



Area of Risk

Design limit test are intended to ensure that system of subsystem designs are adequate to meet specified performance characteristics when exposed to "worst case" environmental conditions expected at the extremes of the operating envelope. Nevertheless, test environments often are not representative of the "worst case" operating environment, resulting in high risk of poor performance during operational use.

Outline for Reducing Risk

- One specific set of system-level test environments based on expected operational (mission profile) environments is used.
- System-level operational test environments are allocated to each subsystem and tailored to the expected operational environment for each subsystem.
- Design limit qualification test environments are based on the "worst case" conditions in the system and subsystem life cycle profiles.
- Contractors are provided with measured environmental data to use in developing test environments.
- Test environments are modified as additional environmental data become available.

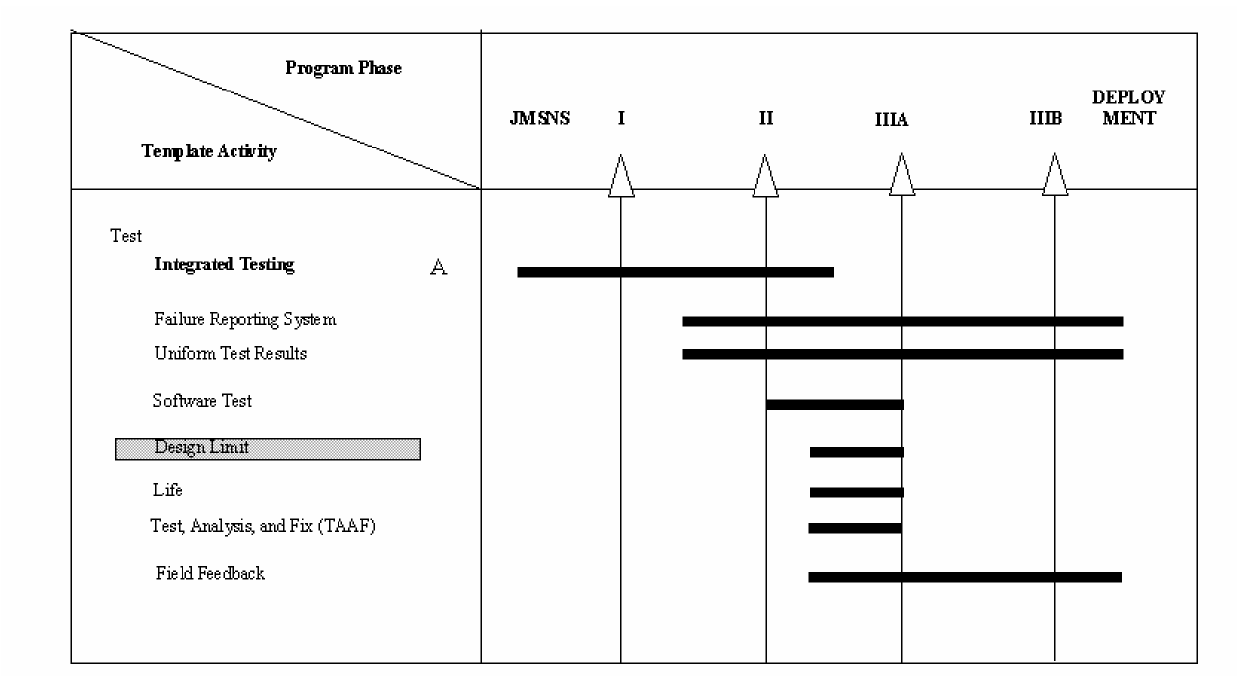
• Failures occurring during design limit qualification testing are investigated thoroughly to determine the mechanisms of failure, so that creative action can be initiated. Timeliness is important to ensure cost-effective design improvements.

• Design limit qualification testing is conducted on critical hardware at the lowest level of assembly.

• A test history file is maintained on design limit qualification tests for future use on the program and as a reference for new programs.

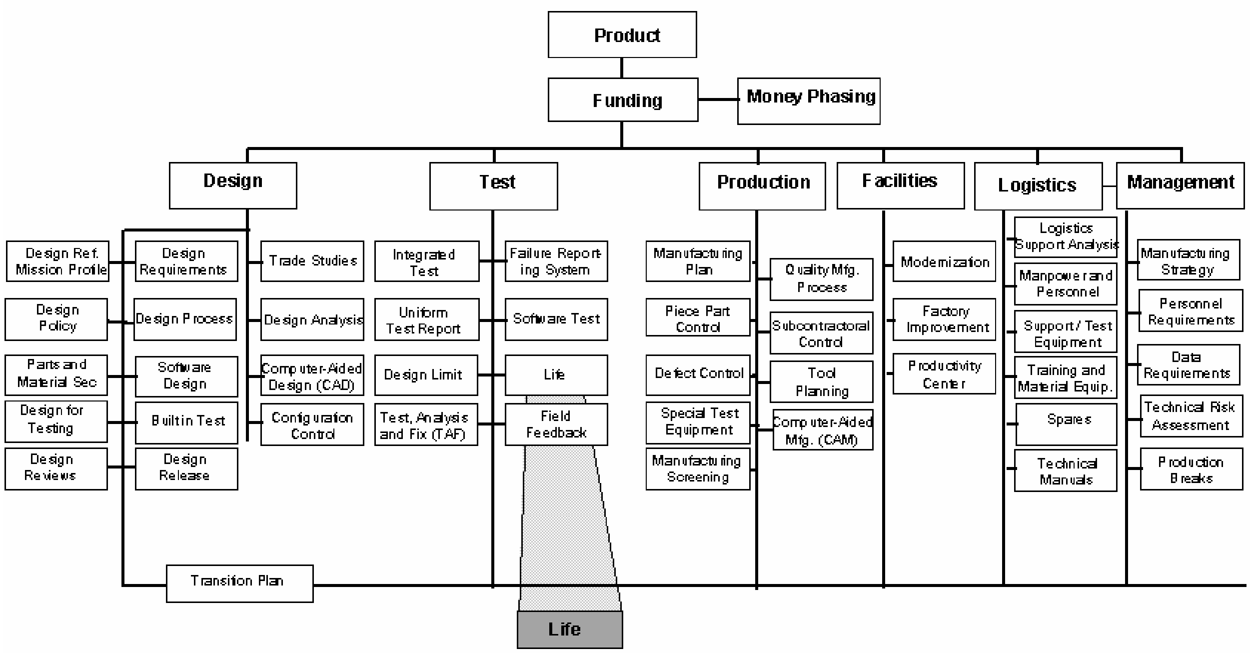
• Subsystem qualification tests are scheduled and conducted so that completion occur before the production decision.

Timeline



Design limit tests ensure that system or subsystem design meet performance requirements when exposed to environmental conditions expected at the extremes of the operating envelope the "worst case" environments of the mission profile.

G. -- Life



Area of Risk

Life tests are intended to assess the adequacy of a particular equipment design when subjected to long-term exposure to certain mission profile environments. Due to the time-consuming nature of these tests, various methods have been used to accelerate test times by exposure to more stringent environments than those expected in actual operational use. These methods may give misleading results due to a lack of understanding of the acceleration factors involved, for example, recent attempts to develop accelerated life tests to verify long-term dormant storage requirements for missiles.

Many weapon system programs are forced into conducting life tests after the systems are deployed and before reliability requirements are achieved. As a result, life tests are performed after the start of production and mostly engineering change proposals (ECPS), and retrofit programs must be initiated in an attempt to “get well” with less than optimum design solutions.

Outline for Reducing Risk

- Include life testing in tie overall system integrated test plan to ensure that testing is conducted in a cost-effective manner and to meet program schedules.

- Use test data from other phases of the test program to augment the system and subsystem life testing by reducing the time required to prove that reliability requirements are met.

- Use life-test data from similar equipment’s operating in the same environment to augment the equipment life testing, in order to gain confidence in the design. For example, this technique is useful particularly when determining the long-term dormant life expectancy of a missile.

• Conduct early assessment of operational life expectancy through realistic life testing that will ensure timely feedback of test results to design activities.

• Develop realistic life test environments based on operational mission profile environments. Experience gained from previous programs is useful in developing life test parameters.

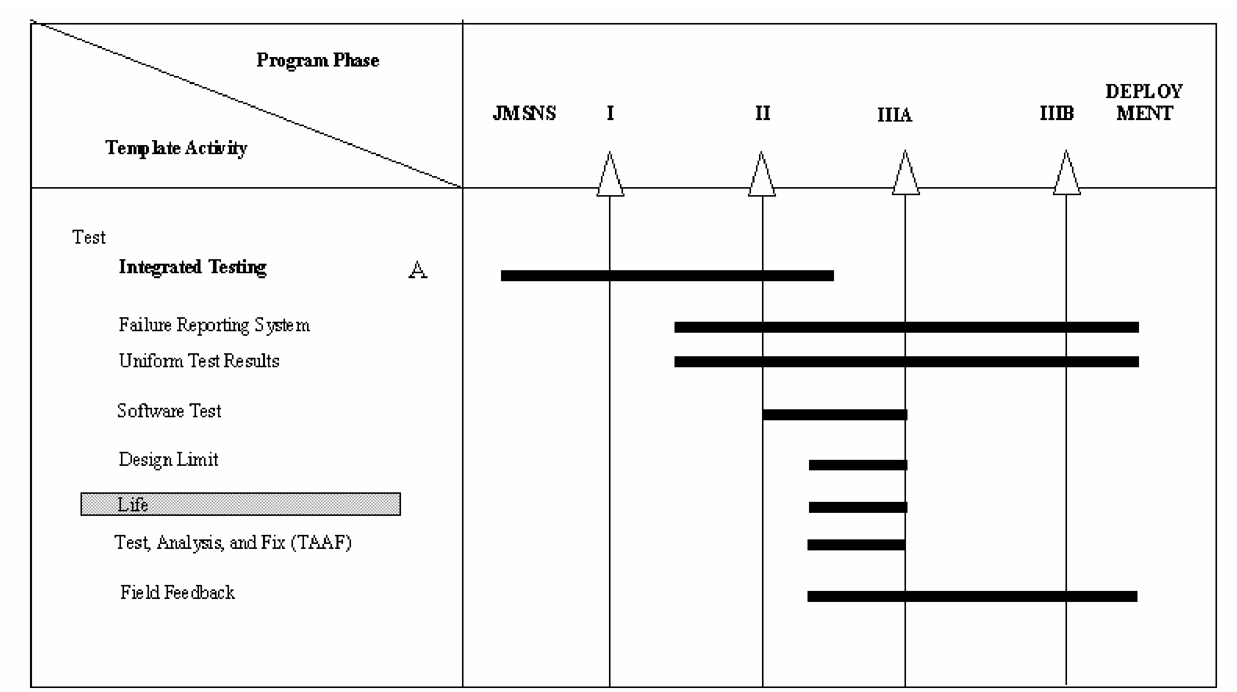
• Use only proven, well understood, accelerated testing techniques in the design of life tests.

• Analyze failure data originating from life tests in sufficient depth to identify the root cause of failure, so that the proper design correction can be implemented.

• A well designed life test is an excellent measure of the level of design maturity.

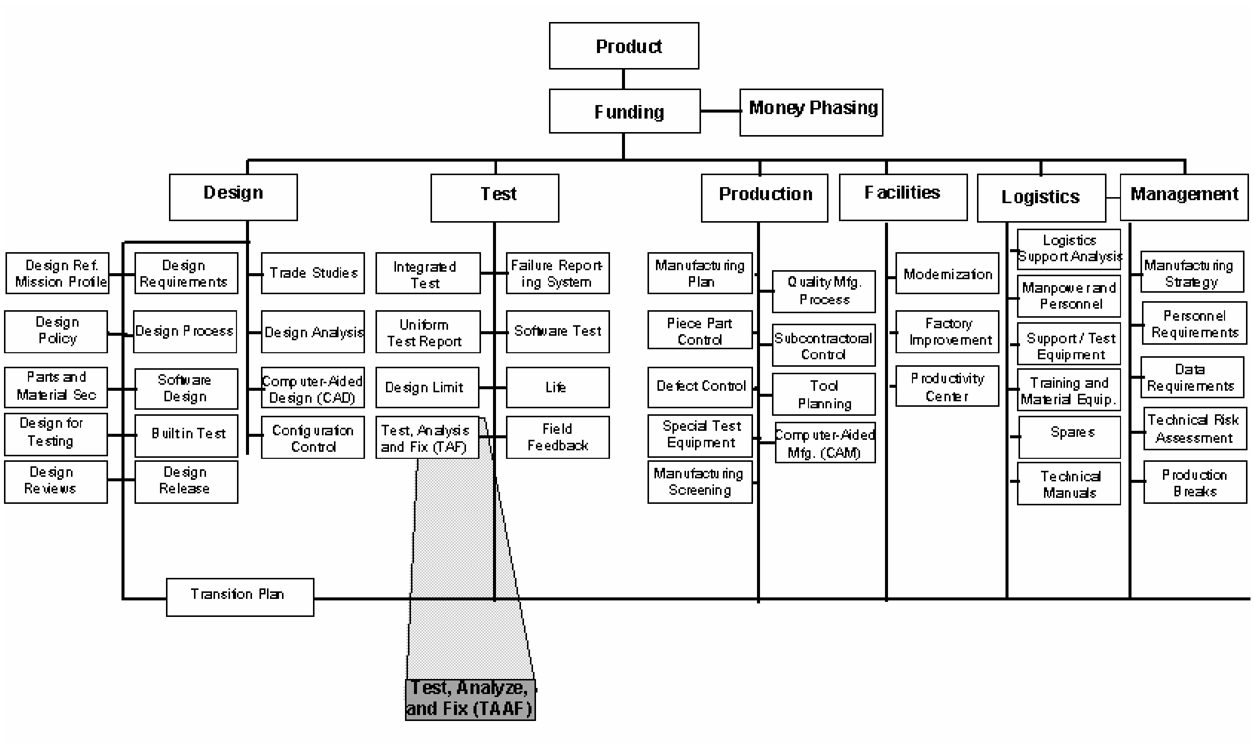
• Fatigue life tests should be conducted to loading spectra that will determine the inherent strength of the parts so that their lives can be recalculated should the operational mission profile be changed or revised test conditions differ from those calculated.

Timeline



A well-designed life test an excellent measure of the level of design maturity and is used to reestablish life characteristics. Life testing is integrated with other development test activities and is completed before design release.

H. -- Test, Analyze, and Fix (TAAF)



Area of Risk

Many past development contracts have not given proper emphasis to reliability development testing, utilizing the TAAF methodology. Instead, they limit their approach to a reliability test to demonstrate a numerical mean time between failure (MTBF) requirement. This latter approach has been ineffective in providing weapon systems with acceptable field reliability. Reliability development testing (TAAF) using simulated mission environments and emphasizing reliability growth has proven a more effective use of limited test resources' and has reduced the risk of allowing systems with poor reliability to transition from development to production. TAAF is consistent with the growth requirement of DoD Directive 5000.40 (reference (g).

Outline for Reducing Risk

- Reliability development tests are performed instead of reliability demonstration tests, which are nonproductive cost and schedule drivers.

- Reliability development test resources are directed to subsystems of low (predicted) reliability when improvement will have a significant influence on overall weapon system reliability.

- If subsystems of high (predicted) reliability exhibit reliability problems during other development tests, such subsystems are incorporated in the reliability development test program.

- For most efficient use of test resources, reliability development tests are integrated with other tests, such as environmental qualification tests, to avoid duplication.

- Reliability development tests use mission profile environments.

- The predicted MTBF is at least 1.25 times the required MTBF (see figure 4-4.).

- An initial MTBF estimate of 30 percent of the predicted MTBF should be used for low risk programs. A substantially lower estimate, as low as 10 percent in some cases, should be used for high risk programs.

- A growth slope of 0.5 can be achieved by a well-executed program.

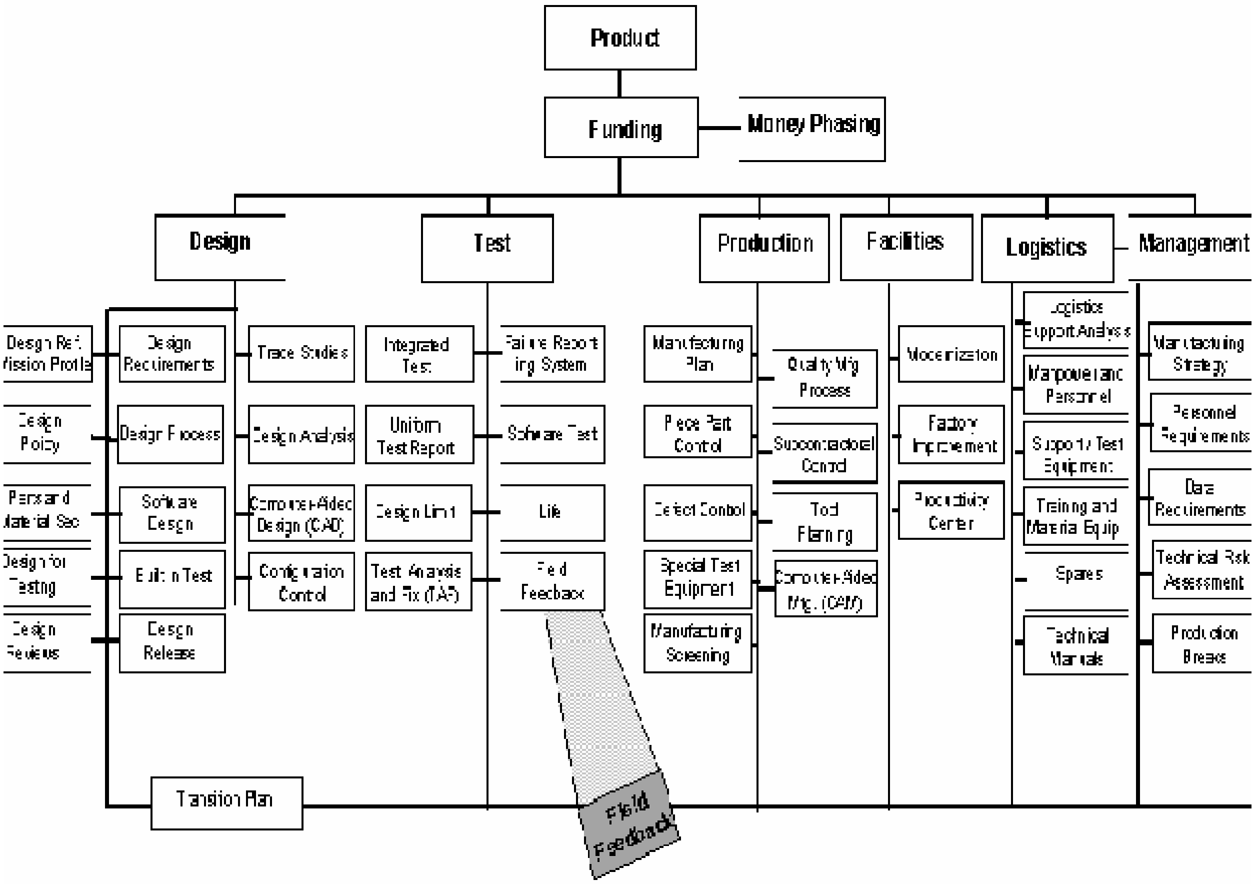
- There are no random failures -- all failures require analysis and implementation of corrective action to prevent their recurrence.

- Results of reliability development tests and other development and operational tests are used to assess reliability.

- Reliability development tests are terminated when further tests produce insignificant improvements.

- A typical reliability development test example is shown in figure 4-4. for both low risk and high risk programs.

TAAF tests are implemented during FSD, to ensure the early incorporation of corrective action necessary for continuous reliability growth. TAAF tests are integrated with other test activities and are completed before the initial production decision.



I. -- Field Feedback

Area of Risk

Early feedback of problems occurring during initial use of weapon systems is essential for the elimination of unforeseen design defects and correction of problems. Feedback of field problems, however, is slow and inadequate, and failed parts are not returned for analysis in a timely manner. Onsite engineering teams can provide adequate reporting and return of-parts, but the usual contractual approach to the use of the teams is to address implementation at contractors; facilities only and not to include provisions for service use at remote sites.

Outline for Reducing Risk

- Weapon systems' contracts provide for an onsite engineering team to observe initial operation, help in identifying problems, provide early feedback of field problems, and provide sufficient data to allow design changes or improvements to the manufacturing process. The duration of this service is established during contract negotiations.

  - The types of problems encountered in initial service operation of new weapon systems require engineering solutions.

- Solutions are enhanced significantly by onsite engineering analysis.

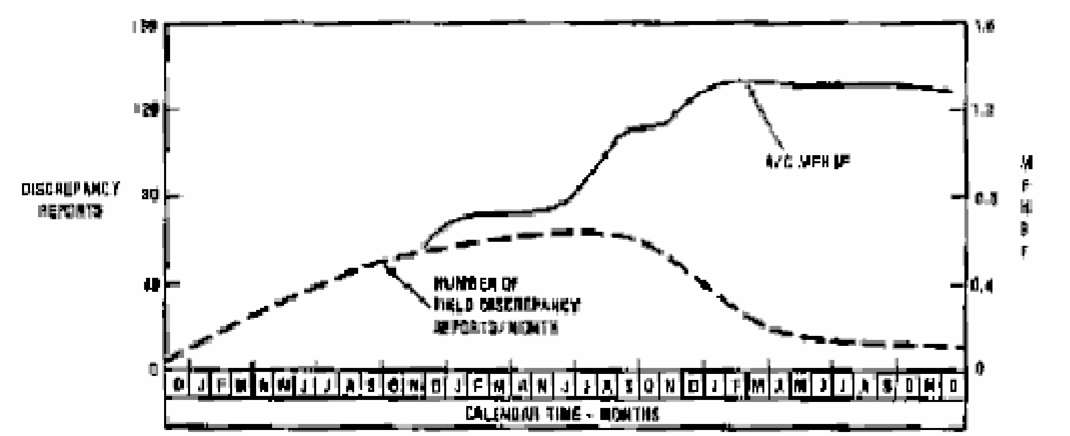
- Experience has demonstrated the effectiveness of the onsite analysis process in improving field reliability of weapon systems.

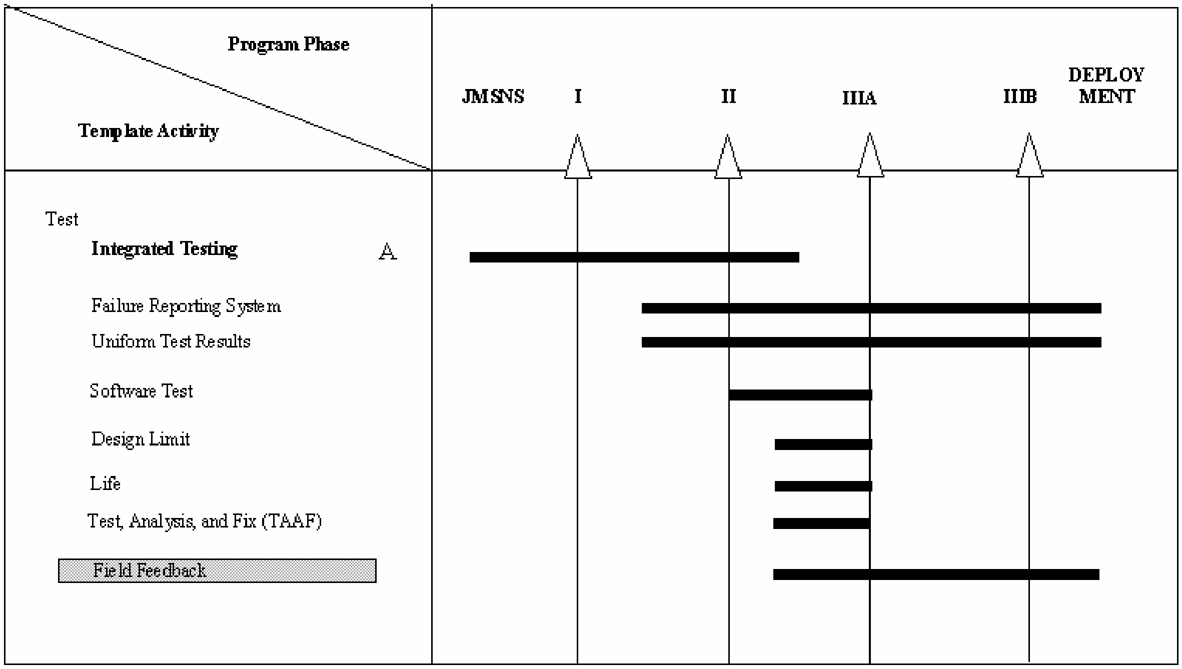
- The final payoff of the onsite engineering team is the improved reliability of the system during service operation. This is illustrated in figure 4-5. for a recent fighter aircraft program. The reliability problems identified in service use contributed the major part of the observed improvement in mean flight hours between failure (MFHBF) and reduction in discrepancy reports.

    – The onsite team is trained adequately.

    – Direct communication link is maintained with the design team.

• Onsite engineering teams are not used on small programs where the risk is low. Judgment is required for effective use.





Early feedback of problems occurring during initial use of weapon systems is essential for elimination of unforeseen design defects and correction of problems caused by the transition to full rate production and tooling. Onsite engineering teams are used as soon as field operations begin and continue through service use to improve the accuracy, quantity, and speed of reporting of field failures and corrective actions.

Next Section